Historic, archived document

Do not assume content reflects current scientific knowledge, policies, or practices.

BELTSVILLE BRANCH
UNITED STATES
DEPARTMENT OF AGRICULTURE
LIBRARY

BOOK NUMBER 1
Ag84C
699910 726-750
1945-1946

USDA, National Agricultural Library
NAL Bldg
10301 Baltimore Blvd
Beltsville, MD 20705-2351

2984C

Circular No. 726

May 1945 • Washington, D. C.

UNITED STATES DEPARTMENT OF AGRICULTURE

LIBRARY
RECEIVED
JUL 1 1945
U. S. DEPARTMENT OF AGRICULTURE
BELTSVILLE BRANCH

USE OF COMMERCIAL FERTILIZERS IN COTTON PRODUCTION

U. S. DEPARTMENT OF AGRICULTURE
LIBRARY
BELTSVILLE BRANCH

By J. J. Skinner, *senior biochemist, Division of Cotton and Other Fiber Crops and Diseases, Bureau of Plant Industry, Soils, and Agricultural Engineering, Agricultural Research Administration*[1]

CONTENTS

	Page
Summary	1
Tonnage of fertilizers used on cotton	2
Nutrient requirements of cotton	4
Nutrients available in the soil	6
Nutrients increased by good crop-management practices	7
Growing winter cover and green-manure crops to supply nitrogen and conserve nutrients	7
Growing summer legumes in rotations to maintain soil fertility	8
Nutrients supplied by commercial fertilizers and the estimated returns	8
Applications of nitrogen, phosphorus, and potash	9
Applications of mixed fertilizers	10
Form and function of fertilizer constituents	11
Nitrogen	11
Phosphorus	12
Potash	12
Secondary plant nutrients	13
Minor plant nutrients	13
Efficient use of commercial fertilizer	14
Fertilizer grades recommended	14
High-analysis fertilizers	15
Addition of non-acid-forming material	16
Application of side dressings	16
Side placement of fertilizers	17
Savings effected by use of higher analysis fertilizers	19
Recommendations to increase yields	23
Literature cited	25

SUMMARY

Yields of cotton per acre determine in large measure the cost of production per pound and the profit in producing this, the principal cash crop of the South. In the southeastern and south central sections of the Cotton Belt the kinds and quantities of fertilizer used have a greater influence on yield and profit than any other factor. Other cultural means of maintaining soil fertility and producing profitable yields are concerned with increasing the acreage of legume cover crops, adopting proper rotations, and improving crop-management practices.

Information concerning the quantities and kinds of commercial fertilizers to be used is becoming increasingly important, for improved fertilizers efficiently used not only increase acre yields of cotton but also increase the oil content of cottonseed, retard nutritional diseases of the cotton plant, and increase the production of long-staple cotton, which is grown principally in that section of the Cotton Belt where commercial fertilizers are essential.

It is important, also, to evaluate the returns that are possible from the use of commercial fertilizers to increase the available nutrient

[1]Data for figures 1, 2, and 11 to 17 were supplied by A. L. Mehring, chemist, Division of Soil and Fertilizer Investigations, of this Bureau.

content of the soil in large cotton-producing regions and to determine means of increasing the use of these fertilizers. Knowledge of the symptoms caused by deficiencies of essential plant nutrients results in a better understanding of the fertilizer requirements for the profitable production of cotton in different soil regions.

The use of high-analysis fertilizer containing materials of low cost per unit of plant food reduces the cost of fertilizer, conserves bags and other materials, and saves freight, handling, and farm labor expense. The use and proper application of improved fertilizers on improved varieties of cotton, the growing of winter legumes more extensively, the rotation of cotton with other crops, including a summer legume, and the elimination of cotton from unsuitable areas make it possible to produce larger yields on fewer acres at reduced cost.

TONNAGE OF FERTILIZERS USED ON COTTON

The available supply of the fertilizer ingredients that furnish essential plant nutrients depends at the present time largely on the demand for these ingredients for other purposes. The number of fertilizer grades manufactured is limited and the concentration of plant nutrients in them has been increased to save manufacturing cost and to conserve materials and labor. Efficient use of available fertilizers in cotton production is aided by a knowledge of the total quantity used, the rates of application of mixed fertilizers and materials, and the returns from these applications in different sections of the Cotton Belt. The increased acreage of oil-producing crops, which are grown extensively in the cotton rotation, has a direct bear-

TABLE 1.—*Cotton acreage fertilized, quantity of fertilizer used, and average yield of cotton per acre in 1943*[1]

Region and State	Acreage fertilized		Quantity applied		Average yield of lint per acre for entire crop[2]
			Average per acre	Total	
Southeastern States:	*1,000 acres*	*Percent*	*Pounds*	*Tons*	*Pounds*
Virginia	35	99	475	8,312	355
North Carolina	856	99	475	203,300	338
South Carolina	1,129	99	470	265,315	291
Georgia	1,564	99	365	285,430	253
Alabama	1,539	98	375	288,562	285
Florida	45	96	315	7,088	174
Total	5,168	.....	412	1,058,007	.....
South Central States:					
Mississippi	1,934	78	235	227,245	354
Louisiana	667	66	195	65,032	349
Arkansas	1,114	58	175	97,475	291
Tennessee	504	70	230	57,960	327
Missouri	101	27	160	8,080	386
Total	4,320	.....	199	455,792	.....
Southwestern States:					
Texas	402	5	175	35,175	174
Oklahoma	16	1	125	1,000	123
Total	418	.....	150	36,175	.....
All others	71	5	195	6,963	383
Grand total	9,977	.....	.....	1,556,937	.....

[1] BUREAU OF AGRICULTURAL ECONOMICS, CROP REPORTING BOARD. COTTON PRODUCTION, 3 pp. August 1943. [Processed.]

[2] BUREAU OF AGRICULTURAL ECONOMICS, CROP REPORTING BOARD. COTTON PRODUCTION, 3 pp. April 1944. [Processed.]

699910

ing on the fertilizer requirements necessary for efficient production of cotton. Correlating fertilizer factors with agronomic data is of value in formulating fertilizer recommendations.

In 1943, 1,556,937 tons of fertilizer were used on 9,977,000 acres of cotton. The estimated acreage fertilized, the rate of application, and the average yield of cotton per acre in 1943 in the fertilizer-using States are given in table 1.

The probable quantity of nitrogen used in the production of cotton in 1943, as estimated by a committee of specialists of the United States Department of Agriculture, assisted by State experiment station and extension workers, is shown in table 2. Approximately 90,500 tons is consumed annually in cotton production, about half of it in mixed fertilizers and half as materials used principally for side dressing. The estimated average rates of nitrogen applied per acre are highest in South Carolina, North Carolina, and Virginia, followed by Georgia and Alabama.

TABLE 2.—*Estimated quantity of nitrogen used and estimated rate of use per acre in the production of cotton, 1943 basis*

Region and State	Tons			Pounds per acre		
	In mixed fertilizer	Chiefly as side dressing	Total	In mixed fertilizer	Chiefly as side dressing	Total
Southeastern States:						
Virginia	291	97	388	18.5	5.9	24.4
North Carolina	5,486	4,490	9,976	14.0	11.6	25.6
South Carolina	7,803	6,919	14,722	14.6	13.0	27.6
Georgia	9,044	6,887	15,931	12.0	8.9	20.9
Florida	313	201	514	9.0	5.8	14.8
Alabama	10,629	5,978	16,607	14.2	8.0	22.2
South Central States:						
Tennessee	1,007	1,643	2,650	2.8	4.5	7.3
Mississippi	5,167	12,058	17,225	3.5	8.2	11.7
Louisiana	1,263	2,275	3,538	2.5	4.6	7.1
Arkansas	2,063	4,595	6,658	2.0	4.5	6.5
Southwestern States:						
Oklahoma	29	.....	29	.3	.....	.3
Texas	1,631	222	1,853	.35	.05	.4
California	573	.....	573	3.2	.....	3.2
Total	45,299	45,365	90,664	.....	.....	.....

The proportion of total fertilizer tonnage used on the cotton crop in 1942 as compared with the quantity used on all other crops in six Southeastern States is shown in figure 1. It is apparent that cotton is a large fertilizer-using crop in these States. In 1943, 99 percent of the acreage planted to cotton was fertilized in Virginia, North Carolina, and Georgia; 98 percent in Alabama; 78 percent in Mississippi; and 66 percent in Louisiana. The cost of fertilizers to cotton growers in 1943 was approximately $44,000,000, an important item of expense in producing the crop in the Southeast. The necessity of using fertilizer efficiently is apparent.

The distribution of fertilizer consumption in the United States by crops fertilized in 1927, 1938, and 1942 is shown in figure 2. Preceding 1938, more fertilizers were used in producing cotton than for any other crop. By 1938 the proportion consumed for cotton was reduced, and by 1942 this was further decreased, principally because of the decrease in cotton acreage in the fertilizer-using section of the Cotton Belt.

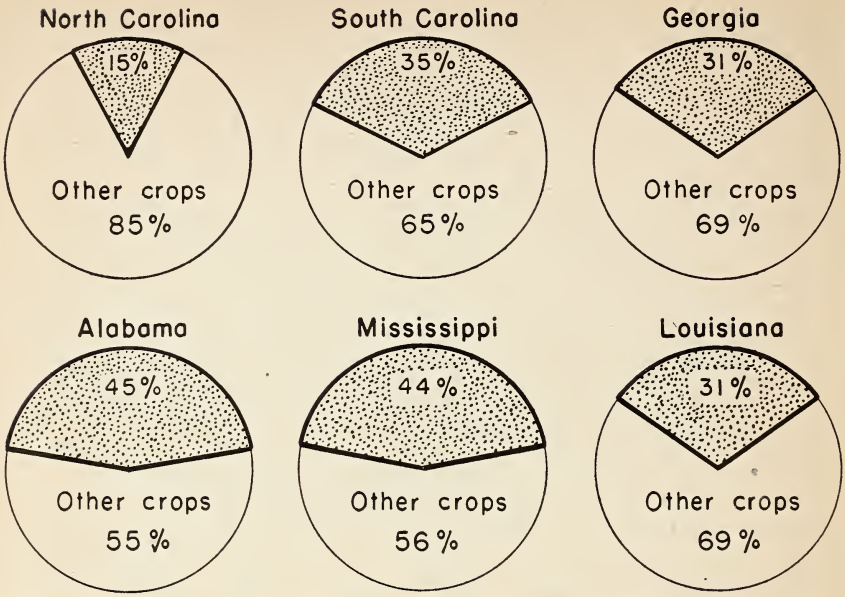


FIGURE 1.—Proportion of total fertilizer tonnage used in producing cotton in six States in 1942.

Based on surveys made by the National Fertilizer Association in 1938, it is estimated that approximately 53 percent of the cotton produced in the South Atlantic States, 35 percent in the South Central States, and 7 percent in the Southwestern States was due to the use of fertilizers; such use is more essential in the South Atlantic States.

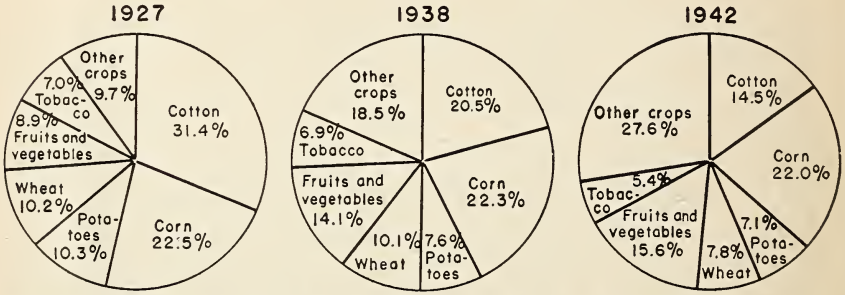


FIGURE 2.—Distribution of fertilizer consumption in the United States by crops fertilized, in 1927, 1938, and 1942.

NUTRIENT REQUIREMENTS OF COTTON

The nutrients consumed by cotton in different soil regions do not vary widely except on soils containing an excess or a deficiency of essential nutrients or where unbalanced fertilizers are used. The average estimated weight of nutrients per acre absorbed by cotton and the estimated weight of nutrients per acre permanently removed by cotton lint and seed grown in 2-year experiments on six soils in Georgia and North Carolina and on seven soils in Texas,

yielding as an average approximately 700 pounds of seed cotton per acre, are given in table 3.

The estimated nutrients absorbed by cotton grown in Georgia and North Carolina are based on analyses made periodically of cotton plants grown on Norfolk, Orangeburg, and Tifton soils of the Atlantic Coastal Plain; on Cecil clay loam and Cecil sandy loam of the Piedmont; and on Clarksville gravelly loam, a limestone valley soil. The soils are of average fertility and received fertilizers annually at rates approximating 400 pounds an acre. Nutrients taken up by cotton grown on Texas soils are based on analyses of plants that were grown in seven soil regions.

TABLE 3.—*Average estimated weight of nutrients per acre absorbed by cotton and of nutrients permanently removed from the soil by cotton lint and seed*

Plant nutrient	Absorbed by cotton in experiments in—		Permanently removed by cotton lint and seed, based on acre yield of—	
	Georgia and North Carolina	Texas	700 pounds of seed cotton	1,400 pounds of seed cotton
	Pounds	*Pounds*	*Pounds*	*Pounds*
Nitrogen (N)	77	64	15.0	30.0
Phosphorus (P_2O_5)	23	17	7.0	14.0
Potash (K_2O)	67	56	7.0	14.0
Calcium (CaO)	79	88	1.5	3.0
Magnesium (MgO)	26	26	2.0	4.0

Cotton plants absorb relatively large quantities of nitrogen, potash, and calcium, compared with phosphorus and magnesium. The quantity of nutrients required to produce a cotton crop is much greater than that permanently removed, for the stalks, leaves, and burs are returned to the soil. The weight of nutrients per acre in the cotton-plant parts that remain on the soil, on the basis of the eastern Cotton Belt experiments in which 700 pounds of seed cotton were produced per acre, are: Nitrogen, 62; phosphorus, 16; potash, 60; calcium, 77; and magnesium, 24. Preventing the loss of these nutrients by leaching during the winter months is important. They are best conserved for crops that follow, by winter cover crops planted in cotton early in fall. Winter cover crops retard leaching (1) by making a surface cover, (2) by heavy root development, and (3) by absorbing the readily available nutrients returned to the soil in turned-under vegetation. Plant residues are important in maintaining the fertility of soils used for cotton production.

While cotton requires more nutrients than many southern agronomic crops, it removes permanently less nutrients from the soil. Commercial plant food is used on cotton at a greater rate than on peanuts, corn, or small grain. Conserving nutrients returned to the soil in cotton plants is perhaps of greater importance than in other crops. Peanuts, now grown extensively in rotation with cotton, remove about five times as much nitrogen and potash and twice as much phosphorus as cotton, when comparisons are made on yields of 700 pounds of seed cotton an acre and 1,000 pounds of nuts and 2,000 pounds of peanut hay. Corn, also grown extensively in rotations with cotton, removes almost twice as much nitrogen when based on a yield of 25 bushels per acre. The weight of nutrients per acre removed in peanuts and corn are shown in table 4.

TABLE 4.—*Weight per acre of plant nutrients permanently removed from the soil by peanuts and corn*

Plant nutrient	Peanuts (hay and nuts)	Corn (ears only)
	Pounds	*Pounds*
Nitrogen (N)	71	28
Phosphorus (P_2O_5)	13	12
Potash (K_2O)	38	11
Calcium (CaO)	31	8
Magnesium (MgO)	41	7

These experiments show that only 12 percent of the total nitrogen and other nutrients taken up by cotton plants is used within 70 to 80 days after the cotton is planted, or by the time cotton is in the squaring period. The uptake of nutrients is greatest in the period between squaring and boll formation, when approximately 58 percent of the total nutrients is used. The constituents of fertilizers applied before planting cotton on sandy soils may be lost through leaching if the nutrients are readily leachable. Data obtained by plant analysis indicate the advantage of cotton fertilizer containing materials supplying essential nutrients in forms that are readily available to the crop but resistant to leaching in the early season, when absorption is slow. Leaching losses may also be minimized and the absorptive demands met by applying part of the fertilizer as a side dressing about 50 to 60 days after planting.

NUTRIENTS AVAILABLE IN THE SOIL

The essential nutrients required by cotton are drawn from the soil, and where these are deficient they can be supplied by commercial plant food. The average available nutrient content of soils of the various regions of the Cotton Belt, as estimated from a large number of soil analyses, is given in table 5. While these data are useful for comparative purposes, they do not represent absolute available quantities of nutrients in the soil at all times. The fertilizer requirement of soil for cotton cannot, in general, be determined by soil analysis alone. Soil analysis, together with data from field fertilizer trials and knowledge from experience, is helpful in determining the fertilizer requirements of soils for profitable cotton production.

Detailed information in regard to the nutrients required by the cotton plant that are available in the soil and the practices by which such nutrients may be made available as quickly and as effectively as possible is discussed in the following sections.

TABLE 5.—*Comparison of average available nutrient content*[1] *of some soil regions of the Cotton Belt*

Soil area	Nitrogen	Weight per acre of available—			
		Phosphorus	Potassium	Calcium	Magnesium
	Percent	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Atlantic and Gulf Coastal Plains	0.035	6–28	68–85	230–500	35–50
Piedmont province	.....	60–85	80–115	500	75
Limestone valleys	.....	57	184	.....	.....
Appalachian Plateaus	.....	35	127	.....	.....
Gulf Coastal Plains	.085	16	71	275	30
Delta and stream bottom soils	.067	92	127	875	45
Mississippi bluff and terrace soils	.066	26	95	521	27
Texas Black Prairie	.136	52	502	.....	.....
Western Texas	.071	154	455	.....	.....

[1]The data on the available mineral nutrients in soils given are obtained by such simple procedures as the sodium-acetate extraction method, and, in the case of Texas soils, by the weak nitric-acid solution method.

The soils of the Coastal Plain used for cotton production contain an estimated average of 0.035 percent nitrogen, compared with about twice this quantity in the Mississippi Delta and stream bottom soils of the south central

and southwestern Cotton Belt, and four times this quantity in soils of the Black Prairie of Texas.

The available nitrogen content of southeastern soils is generally low, except in soils rich in organic matter or in those where the nitrogen has been increased by growing leguminous crops for turning under. Available phosphoric acid is low in virgin soils, but with the practice of using high ratios of this nutrient in cotton fertilizers the supply has accumulated with time and intensity of cultivation. The available potash, which was low in virgin soils, has been further decreased in recent years by growing peanuts and soybeans, two large potash-consuming crops. Soils of the Atlantic and Gulf Coastal Plains are lower in essential nutrients than those in other regions, and this may account for the use of large quantities of commercial fertilizers.

NUTRIENTS INCREASED BY GOOD CROP-MANAGEMENT PRACTICES

Available nutrients in the soil that are essential for cotton may be maintained by the following practices: (1) Using adequate quantities of efficient fertilizers on each crop in a rotation with cotton, (2) liming, (3) growing winter legumes for turning under, and (4) rotating cotton with other crops.

The efficient fertilization of all crops in a rotation prevents a deficiency of nutrients essential for growing cotton. For instance, adequate potash and lime supplied to peanuts, sufficient phosphorus and potash supplied to soybeans, and adequate nitrogen with small rates of phosphorus and potash supplied to corn play an important part in maintaining or increasing the available nutrients of the soils. Phosphorus and potash applied to a preceding crop are beneficial to cotton.

Liming (*21, 23*)[2] a crop in the rotation and using non-acid-forming fertilizers containing dolomitic limestone have the following benefits: (1) They assure available magnesium and calcium, (2) increase the availability of phosphorus, (3) reduce leaching of potash from the soil, (4) prevent excessive soil acidity, and (5) improve the soil for winter cover crops.

GROWING WINTER COVER AND GREEN-MANURE CROPS TO SUPPLY NITROGEN AND CONSERVE NUTRIENTS

Planted in cotton and other crops in the rotation to improve the soil, winter legumes (1) supply nitrogen for the cash crop, (2) maintain the organic matter, (3) improve the physical condition, (4) increase the moisture-holding capacity, (5) prevent leaching of plant nutrients, (6) make soil nutrients available, and (7) increase cotton yields.

Successful crops of winter legumes grown in cotton and corn may produce 12,000 to 17,000 pounds of green vegetation per acre, as shown by experiments at the Georgia Coastal Plain Experiment Station over a 16-year period. The vegetation turned under is estimated to add to the soil annually more than 60 pounds of nitrogen per acre, the equivalent of almost 400 pounds of sodium nitrate, or about 1,000 pounds of a fertilizer containing 6 percent nitrogen. Vetch, clover, and Austrian Winter peas, grown in cotton and corn in experiments in the northern Coastal Plain where conditions for winter cover crops are less favorable, contributed an average estimated nitrogen supply of about 40 pounds per acre. On most soils, yields of cotton following winter legumes should be as high as on winter fallow land fertilized with 600 pounds of a 4- to 6-percent nitrogen fertilizer, or even higher.

The organic matter in soils planted to cotton may be increased and maintained by growing and turning under winter legume crops of vetch, peas, and clover. This was shown by experiments in Georgia, where after 14 years the organic matter was increased to 0.723 percent by such practice, compared with 0.610 for winter fallow land. The nitrogen was 0.052 percent for soil growing winter legumes as compared with 0.037 for winter fallow land.

The leaching of nutrients from the soil during winter may be reduced by growing summer or winter legumes or nonlegumes in the rotation, as shown by experiments at the Alabama Agricultural Experiment Station. Here the average percentage of applied potassium that was leached from the surface of eight soils was 20 percent with no winter legumes and only 3 percent with winter legumes in the rotation. In a rotation including summer legumes, an average of 57 percent of the added nitrogen was leached from the soil

[2] Italic numbers in parentheses refer to Literature Cited, p. 25.

when the summer legume was turned under in fall and no winter cover crop was grown, and only 9 percent was lost when oats were grown as a winter cover crop.

The value of winter legumes plowed under in a cotton-production program is shown by experiments made for 14 years at the Georgia Coastal Plain Experiment Station, where soil and cultural conditions are very good for winter legumes. An average increase of 620 pounds per acre of seed cotton was obtained when cotton followed winter legumes, as compared with the increase when cotton followed a winter of fallow. The average increase in yield in 13 experiments in 5 States where cotton followed good stands of legumes that were turned under was 403 pounds of seed cotton per acre as compared with yields of seed cotton fallow. A survey of 386 growers in North Carolina, South Carolina, Georgia, and Alabama who produced cotton on 1,877 acres showed that the increase in yield of cotton following winter legume cover crops, as compared with cotton following fallow, ranged from 120 to 471 pounds per acre of seed cotton (*11*).

The yield of cotton in many experiments in the Southern States where this crop followed winter legumes turned under showed an average increase in seed cotton of approximately 270 pounds per acre greater than cotton following winter fallow. Inasmuch as this summary includes results of experiments on the principal soil classes on which cotton is grown in the Southeastern and South Central States and on which stands and vegetative growth of cover crops varied from poor to good, this figure may be assumed as the probable increase that may be expected from winter cover crops grown under general or average soil and cultural conditions.

Legume crops most commonly grown with cotton for winter cover and green manure (*9, 10, 16, 17*) are the vetches, Austrian Winter peas, and crimson clover. Nonlegumes—rye, oats, and wheat—may be used as winter cover crops. Although they do not gather nitrogen from the air or increase the soil supply of nitrogen they benefit the soil by (1) taking up nutrients that are returned to the soil in the vegetation, (2) reducing leaching of nutrients during winter, (3) increasing soil organic matter, and (4) preventing erosion. Nitrogen applied in low rates to nonlegumes in fall improves growth and gives better erosion protection. Small applications of nitrogen when the vegetation is turned under in spring aid decomposition and should benefit cotton.

GROWING SUMMER LEGUMES IN ROTATIONS TO MAINTAIN SOIL FERTILITY

Summer legumes and other crops grown in rotation with cotton are recognized as a means of maintaining the supply of plant nutrients and organic matter in the soil. The effect of crop rotation on the organic matter is shown by the results of a 9-year experiment with various crop rotations in the Southeast. In this experiment organic matter in the soil in which cotton was grown continuously was 1.26 percent; in rotation with grain and a legume, 2.01 percent; and in rotation with a nonlegume, 1.63 percent. Although the use of land exclusively for a summer green-manure crop precludes the possibility of growing a regular cash crop, nevertheless legume crops grown for seed, when properly fertilized, contribute to the maintenance of soil fertility. Crop rotation increases the yield of cotton above that obtained where continuous cotton culture is practiced. In experiments made in six States over a long period of years increased yields of approximately 200 pounds of seed cotton per acre were recorded where cotton was grown in rotation, as compared with yields where cotton was grown continuously.

Some of the summer legume crops that are suitable for soil improvement and are grown in rotation in various sections of the Cotton Belt (*8*) are soybeans, velvetbeans, lespedeza, crotalaria, Sudan grass, and cowpeas.

NUTRIENTS SUPPLIED BY COMMERCIAL FERTILIZERS AND THE ESTIMATED RETURNS

Soils that do not supply adequately available nutrients to cotton at all periods of growth should be supplemented by commercial fertilizer. To determine the quantity and kind of fertilizer for efficient production on different soils, the following information, which is available for many regions, is helpful: (1) Available nutrient content of the soil; (2) its physical and chemical nature, which determines its capacity to retain moisture and nutrients and to resist leaching by rainfall; and (3) its capacity

for fixation of chemical elements. Fertilizer additions to soils required for profitable production may be determined by correlating these data with results of field-fertilizer experiments. Cultural and crop-management practices, including crop rotation, quantity of organic matter turned under as residues from other crops in the rotation, and the extent to which summer and winter legumes are grown as manure crops have a bearing on the quantity and grade of fertilizer required for efficient production.

APPLICATIONS OF NITROGEN, PHOSPHORUS, AND POTASH

Based on field experiments, estimates have been made of cotton produced by the three major nutrients—nitrogen, phosphorus, and potash—supplied in commercial fertilizers. Average increased yields from different nitrogen levels indicated by the experiments are shown in figure 3. In a large number

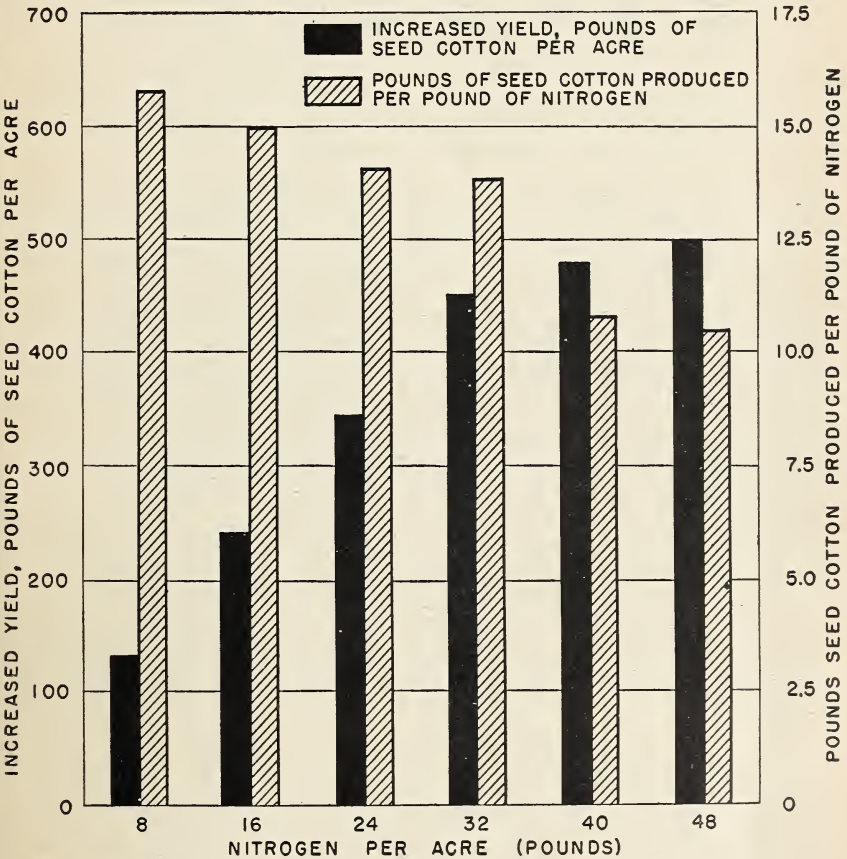


FIGURE 3.—Estimated increased yields of cotton as a result of the application of nitrogen, based on experiments covering long periods in the fertilizer-using section of the Cotton Belt.

of experiments on a wide range of soils over a long period, the average increased yield as a result of nitrogen applications at rates of 8 to 32 pounds per acre ranges from 13.5 to 15.5 pounds of seed cotton per pound of nitrogen. The yield increases when more nitrogen is applied, up to 48 pounds per acre. The extent of the increase is not so great above 32 pounds.

Data from experiments with phosphoric acid (fig. 4) indicate that increased yields as the result of applying phosphorus to cotton are of less magnitude than those from nitrogen. A gradual but very small increase in

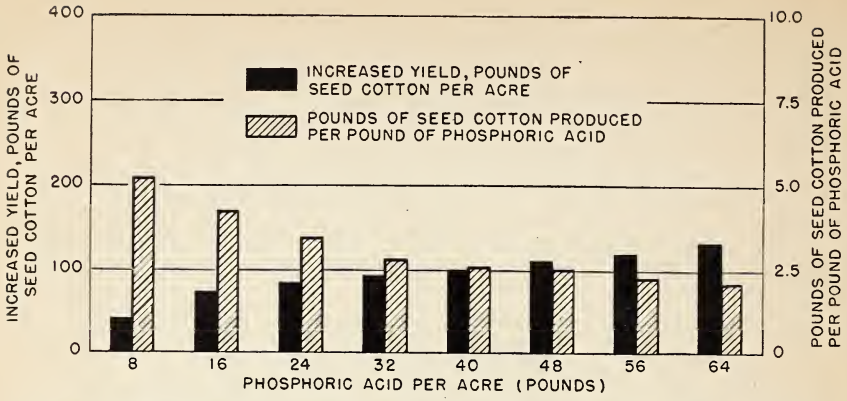


FIGURE 4.—Estimated increased yields of cotton as a result of the application of phosphoric acid, based on experiments covering long periods in the fertilizer-using section of the Cotton Belt.

yield results as larger applications are made. The average production resulting from an application of phosphoric acid at the rate of 16 pounds to the acre is approximately 4 pounds of seed cotton per pound of phosphoric acid. A pound of phosphoric acid produced approximately 2.5 pounds of seed cotton when applied at rates of 32 to 40 pounds per acre.

Estimating the effect of potash on cotton yields is complicated by the fact that many experiments have been conducted on soils that are exceptionally deficient in potash. Figure 5 shows the average yields from the application of potash at different rates, based on the results of experiments on all soils and only on soils not deficient in potash. There was an average increase in cotton yields on all soils to which an increased application of potash up to 48 pounds per acre was made. Seed cotton produced per pound of potash decreases with increase in rate of potash applied, ranging from 9 to 15 pounds of seed cotton per pound of potash when used at the rate of 8 to 32 pounds per acre.

Based on an average response to potash in these experiments, excluding potash-deficient soils, yields increase with increased rate of potash up to the 32-pound level. Production per pound of potash is approximately 8 pounds of seed cotton with applications of from 8 to 16 pounds of potash.

A larger percentage of cotton produced by fertilizers is attributed to nitrogen than to phosphoric acid or potash. In general, 50 to 55 percent of the increase may be attributed to nitrogen, 15 to 20 percent to phosphoric acid, and 25 to 30 percent to potash. Since the expansion of peanut and soybean acreage in the Cotton Belt, the importance of potash for cotton has increased.

APPLICATIONS OF MIXED FERTILIZERS

The average application of plant food to cotton in North Carolina in 1938 (*22*) was 25 pounds of nitrogen, 36 pounds of phosphoric acid, and 20 pounds of potash per acre, the equivalent of 500 pounds of a 5-7-4 fertilizer. Assuming an increased yield of 12 pounds of seed cotton per pound of nitrogen, 3 pounds per pound of phosphoric acid, and 8 pounds per pound of potash, the total increased yield from the fertilizer would be 568 pounds of cotton. This represents a return of approximately 115 pounds of seed cotton, or 41.5 pounds of lint per 100 pounds of fertilizer—approximately the return that the experiments indicate may be expected from fertilizer. In more than 150 experiments by the United States Department of Agriculture and State agricultural experiment stations on the principal soil types used for cotton production in 7 States and covering a range of 18 years, the average increase of cotton due to fertilizers, used at rates of 200 to 600 pounds per acre, is approximately 1.6 bales per ton of fertilizer; that is, 40 pounds of lint per 100 pounds of fertilizer. Based on these results, cotton produced in 1943 by applications of commercial fertilizer is estimated at approximately 2,491,009 bales.

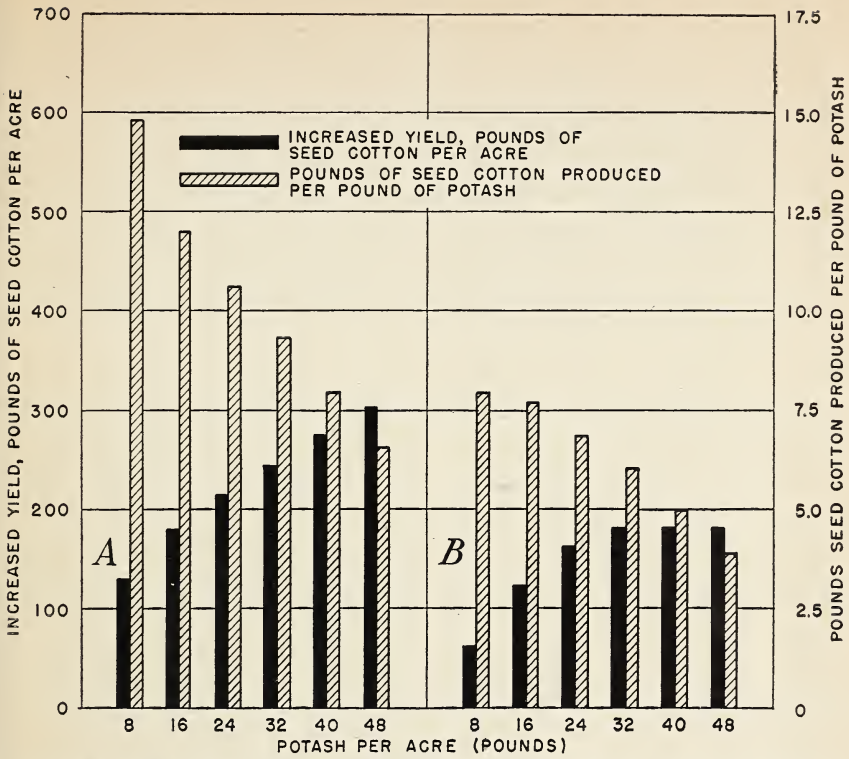


FIGURE 5.—Estimated increased yields of cotton as a result of the application of potash, based on experiments covering long periods in the fertilizer-using section of the Cotton Belt: *A*, Results on all soils; *B*, results on soils not deficient in potash.

FORM AND FUNCTION OF FERTILIZER CONSTITUENTS

Nitrogen, phosphorus, and potash are essential constituents of fertilizer for cotton. For maximum efficiency, the fertilizer must supply these nutrients as well as adequate quantities of calcium, magnesium, and sulfur. It should provide available nutrients at all stages of growth, and these should be resistant to excessive leaching from the soil. The fertilizer should be so compounded that its continued use will not have a harmful effect on the soil, such as making it too acid.

NITROGEN

The following forms of nitrogen (*2, 6, 12, 13, 14, 15, 19, 20*) are suitable for cotton: (1) Nitrate, as sodium nitrate and calcium nitrate; (2) ammonia, as ammonium sulfate, ammonium nitrate that contains both nitrate and ammonia, and liquid anhydrous ammonia; (3) water-soluble organic nitrogen, which includes urea; and (4) water-insoluble organic nitrogen, as processed tankage, cottonseed meal, and fish scrap.

Nitrate nitrogen is readily available but is easily leached from the soil. This quality makes it effective when used as a side dressing after cotton is up. The ammonia salts are readily available, but are not readily leached from the soil, a desirable quality for cotton fertilizers. They are acid-forming, but are suitable for use in mixed fertilizers when properly compounded

with dolomitic limestone to make them non-acid-forming. When fertilizers are neutral or are used on limed soil there is little if any difference in the efficiency of different sources of nitrogen.

Natural organic-nitrogen materials are effective for preplanting applications when used as part of the nitrogen in mixed fertilizers. This form of nitrogen is slowly available and resistant to excessive leaching. Its demand for stock feed and its cost limit the supply for fertilizer use. Inorganic and soluble-organic nitrogen, properly compounded, give equally good results.

Without an adequate supply of available nitrogen, cotton plants fail to grow and produce well. Nitrogen-deficiency symptoms are characterized by relatively meager growth and yellow-green foliage, especially in the older leaves. An adequate supply of nitrogen produces rapid growth, dark foliage, and early setting of squares and bolls; an oversupply may produce excessive vegetative growth, resulting in dense shade, few bolls, and increased vulnerability to the boll weevil (*4*).

PHOSPHORUS

Superphosphate is the principal source of phosphoric acid in mixed fertilizers used on cotton. It also supplies such other essential plant foods as calcium and sulfur. Several grades are manufactured, one containing upward of 45 percent phosphoric acid. Superphosphate, ammonium phosphate—a double salt containing nitrogen and phosphoric acid—and potassium metaphosphate—a double salt containing phosphoric acid and potash—are efficient sources of phosphoric acid.

These phosphate salts, containing high percentages of phosphoric acid, of phosphoric acid and nitrogen, or of phosphoric acid and potash, when used with nitrogen and potash sources containing high plant-food content make possible the manufacture of high-analysis fertilizers that can be used advantageously on cotton.

One important effect of phosphate is to hasten the maturing and opening of cotton. Deficiency of phosphorus is shown by yellowing or dying of the lower leaves, the plants becoming dark green, and the leaves and stems remaining small (*4*).

POTASH

Potash salts suitable for use in fertilizers for cotton are potassium chloride, potassium sulfate, potassium nitrate, manure salt, and sulfate of potash-magnesia. Potassium chloride is most generally used, although both potassium chloride and potassium sulfate contain high percentages of potash.

The different sources of potash do not show a wide variation in their effects on cotton yields or in the reduction of loss from rust or wilt. Without sufficient available potash cotton plants show reduced vigor and are more susceptible to disease. Potash-deficiency symptoms are first shown in the leaf by a yellowish-white mottling. The color changes to light yellowish green with yellow spots appearing between the veins, the centers of which die. Numerous brown specks also occur at the tip, around the margin, and between the veins. The tip and margin of the leaves break down first and curve downward, and the whole leaf finally becomes reddish brown, dries, and is shed prematurely. This premature shedding prevents the proper development of bolls, so that they are dwarfed and immature (*4*).

Potash reduces the loss of cotton from wilt. In the experiments in Texas with 600 pounds of 6-8-0 fertilizer per acre, approximately 46 percent of the cotton wilted; when 4-percent potash fertilizer was added, it reduced the wilt to 33 percent; and when an 8-percent grade was used, to about 21 percent. The yields of seed cotton from the three fertilizers were, respectively, 677, 870, and 948 pounds per acre. Comparable results have been obtained in other States.

Potash is effective in controlling the rust of cotton. In experiments in North Carolina on Piedmont soil, 8 to 16 pounds per acre of potash reduced the percentage of plants affected with cotton rust and gave an increased yield of 230 to 240 pounds of seed cotton as compared with cotton not treated with potash; 32 to 48 pounds of potash controlled the rust and gave an increased yield of 580 to 600 pounds.

Potash increases the percentage of oil in the cottonseed. In an experiment made by the Georgia Coastal Plain Experiment Station, the oil content of delinted seed was increased from 19.79 percent with the application of 20 pounds of potash per acre; to 21.8 percent with the application of 40 pounds;

and to 23.7 percent with the application of 80 pounds. Yields of cottonseed oil per acre were 78.4, 103.6, and 131.7 pounds, respectively, for the different potash applications.

SECONDARY PLANT NUTRIENTS

Adequate calcium and sulfur are supplied to cotton in fertilizer materials that provide nitrogen, phosphoric acid, and potash, such as ammonium sulfate, superphosphate, and potassium sulfate. All or some of these materials are ingredients of most cotton fertilizers, and they are essential constituents of an efficient fertilizer. Calcium- and sulfur-deficiency symptoms in cotton seldom occur in the southeastern Cotton Belt. A lack of available calcium results in retarded growth, in the development of thick short stems and lack of firmness and turgidity, and in the appearance of yellow leaves in the upper part of the plant, while the lower leaves remain green.

Cotton grown with inadequate sulfur develops a light-green color, which shows first in the lower leaves in young plants; later the color changes to yellowish green. The stalks and branches grow long and slender, a response that is not shown when the plants are grown with an inadequate supply of nitrogen, phosphoric acid, and potash.

Magnesium is important for efficient cotton fertilization. The soils of the Southeast show widespread deficiency of this element. Magnesium is supplied from dolomitic limestone used as a filler and to make fertilizers non-acid-forming; when available, it may be supplied as magnesium sulfate or potassium magnesium sulfate. Magnesium-deficiency symptoms are often confused with those of potash deficiency, as cotton may exhibit symptoms due to the deficiency of both elements. Characteristic magnesium-deficiency symptoms are a purple-red leaf with green veins and a premature shedding of the leaves, with the lower leaves falling first. It may be controlled by use of dolomitic limestone in fertilizer.

MINOR PLANT NUTRIENTS

Additions of manganese, zinc, copper, or boron to fertilizers do not increase their efficiency for cotton except locally or on soils that have been overlimed. Experiments with these trace elements in standard and high-analysis fertilizers have not indicated that they are needed as plant nutrients on cotton soils of any extensive areas at this time. Symptoms of manganese deficiency in cotton have been observed on the shell soils of Florida and in small areas in the coastal sections of other States. Symptoms of boron deficiency have

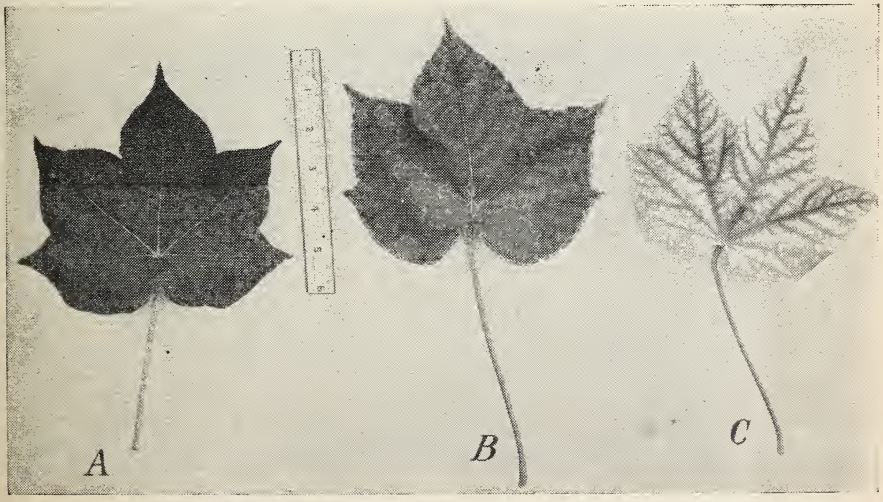


FIGURE 6.—Manganese-deficiency symptoms in the leaves of cotton: *A*, Normal leaf; *B*, mild or early deficiency; *C*, extreme or late deficiency. Extreme deficiency in *C* is indicated by the chlorotic leaf with dark-green ribs. (Courtesy of the New Jersey Agricultural Experiment Station.)

been noted on overlimed soils, and zinc deficiency has been indicated in sections of the sea-island Cotton Belt in Florida. It is not economical to include these supplemental elements in cotton fertilizers generally. Separate applications of any of these minor elements may be made when it is known that the soil responds to their use. Suitable rates of application are as follows: 50 to 100 pounds per acre for manganese sulfate; 10 pounds of copper sulfate; 2 to 5 pounds of boron; and 25 to 30 pounds of zinc.

In the absence of adequate quantities of manganese, the upper or younger leaves are the first to show symptoms of lack of chlorophyll. These symptoms develop slowly and produce the form of chlorosis shown in figure 6. In the affected leaves, the chlorophyll slowly disappears and the leaf takes on a yellowish-gray or sometimes a reddish-gray coloration. Finally necrosis appears in the mottled areas. If necrosis has not developed beyond the slightly mottled stage, the addition of manganese to the soil will check it; it can also be controlled by spraying the foliage with a weak solution of manganese sulfate.

Zinc deficiency is shown by a yellowing of the cotton leaves, which become extremely mottled, show dead areas, and remain small, narrow, and thin.

Symptoms of copper deficiency in the cotton plant are not well known, except that the plants fail to make normal growth and yield, the leaves lack their normal firmness, and the root development is exceedingly poor. This element may be deficient in dark-colored and highly organic soils, although these are not planted extensively to cotton.

Boron deficiency appears in the terminal growth of the plant. There is a necrosis of growing points, a yellowing of the young leaves, and an abscission of bolls and of blossom buds.

EFFICIENT USE OF COMMERCIAL FERTILIZER

FERTILIZER GRADES RECOMMENDED

Fertilizer grades, authorized for manufacture under wartime regulations and recommended by State experiment stations and the United States Department of Agriculture for use on cotton in large areas in the eastern and midwestern Cotton Belts, include a mixture containing nitrogen, phosphoric acid, and potash in a 1-2-1 ratio. For preplanting application to the 1944 and 1945 crops, fertilizer analyzing 5 percent nitrogen, 10 percent phosphoric acid, and 5 percent potash was approved for manufacture in most of the cotton States and was indicated for use where cotton is grown continuously or in rotation with a nonlegume in the northern section of the Atlantic Coastal Plain, in the Gulf Coastal Plain, and in the interior coastal plains of the central and midwestern Cotton Belt (*1, 3*). For cotton in the southern Atlantic Coastal Plain and related soil regions of this belt, a 6-8-4 mixture is recommended. For cotton grown in rotation with peanuts and legumes or on land inherently deficient in potash, as the Tifton soil series of the Atlantic Coastal Plain and the highland soils of Mississippi, a 3-9-9 or 4-8-8 grade is preferred and recommended.

In general, higher phosphorus mixtures are indicated for cotton in the Piedmont, where a 4-12-4 or a 4-10-4 grade is recommended for cotton grown without legumes in the rotation, and 2-10-6 or a 3-12-6 grade for cotton in rotation with legumes and where large quantities of plant residue are turned under. The general recommendations for fertilizing cotton in the Southeastern States are remarkably consistent.

The fertilizer requirements for cotton in the Mississippi Delta and other river-bottom soils vary widely from those of the southeastern Cotton Belt in that nitrogen only is required, although on many soils of the eastern part of the Delta cotton responds to phosphorus and

potash as well as to nitrogen. Fertilizer recommendations for the Delta as a whole call for 32 to 40 pounds per acre of nitrogen.

Fertilizer mixtures suggested for general use on cotton in large soil areas, applied at a rate of about 400 pounds per acre before planting and supplemented with additional nitrogen and potash applied as a side dressing, supply 36 to 40 pounds per acre of each nutrient. The preplanting application of 400 pounds per acre of a 5-10-5 fertilizer supplies 20 pounds of nitrogen, 40 pounds of phosphoric acid, and 20 pounds of potash. Side application of 16 to 20 pounds per acre of nitrogen and potash, together with the preplanting application, supplies the desired quantity of nutrients. A side dressing of nitrogen is desirable on sandy soils, and of both nitrogen and potash on potash-deficient soils and for cotton in rotation with peanuts and soybeans grown for seed.

Fertilizer recommendations for cotton grown under different crop-management practices and rotations in the various soil regions are made currently by State agricultural experiment stations, and they should be consulted. The recommended analyses may change slightly from time to time, on account of economic conditions.

Cotton perhaps does not utilize all the phosphorus supplied in the 5-10-5 grade generally recommended for the crop over large areas. The nutrients required for cotton, as determined by plant analyses, and the requirements based on returns from applied phosphoric acid computed from field experiments do not seem to justify the use of such large quantities of this nutrient as of nitrogen or potash.

Nitrogen, phosphoric acid, and potash supplied by commercial fertilizer to the extent of 36 pounds per acre of each nutrient should be profitable and yet adequate to supply the needs of cotton, except under unusual soil conditions or unusual crop-management practices. Soil enriched with nitrogen by crop residues and legume crops may need less than half this quantity of commercial nitrogen, and soil depleted of potash by soil-depleting crops may need more potash for profitable production. Although 36 pounds per acre of phosphoric acid is perhaps more than is required to produce a profitable crop, it aids in its maturity and benefits soil-improvement crops that may follow cotton.

HIGH-ANALYSIS FERTILIZERS

Fertilizers containing higher percentages of nitrogen, phosphoric acid, and potash than formerly used contribute to the efficiency of fertilizers for cotton. Yields are as great with high-analysis fertilizers such as 5-10-5 as with lower grades such as 4-8-4, when equivalent weights per acre of nitrogen, phosphoric acid, and potash are applied. The high-analysis fertilizer contains less total salts for each unit of plant nutrients furnished than low-analysis fertilizer and is less apt to have an unfavorable effect on germination and stand. Five hundred pounds of 4-8-8 fertilizer contain more total salts than 400 pounds of 5-10-10, and likewise 300 pounds of 12-16-12 contain less potential plant-injury factors, in terms of total salts, than 600 pounds of 6-8-6.

The practical way to increase the nutrient content of fertilizers for cotton is to increase 16- to 20-unit mixtures to 24- and 25-unit mixtures. Fertilizer grades containing upward of 20 units of plant

food were approved for use on cotton by agricultural leaders and authorized for manufacture in 1944 and 1945.

ADDITION OF NON-ACID-FORMING MATERIAL

The inclusion of dolomitic limestone in fertilizers containing acid-forming nitrogen salts makes them more effective. The quantities of limestone required to neutralize 100 pounds of some commonly used nitrogens are as follows: 110 pounds for ammonium sulfate, 55 pounds for ammonium phosphate, 148 pounds for anhydrous ammonia; 50 to 80 pounds for nitrogen solutions; 75 pounds for Uramon; and about 10 pounds for cottonseed meal and tankage. Fertilizer grades suitable for cotton containing these nitrogen sources should contain 250 to 350 pounds of dolomitic limestone per ton to make them non-acid-forming. Neutralizing the fertilizer with dolomitic limestone has the following effects: (1) It maintains the soil pH at approximately the original level; (2) it increases available magnesium in the soil; and (3) it supplies magnesium to the plant at all stages of growth. The use of limestone makes the fertilizer more efficient, as indicated by the results of experiments on the principal soils of the southeastern Cotton Belt, where yields were increased from 30 to 150 pounds of seed cotton per acre.

APPLICATION OF SIDE DRESSINGS

The efficiency of fertilizer for cotton grown on some soils is increased by making fertilizer applications after cotton has come up. Nitrogen applied at the first cultivation of cotton after it is thinned, in addition to the fertilizer applied at planting, promotes rapid growth early in the season and results in earlier blooming and earlier boll formation. The use of leaching-resistant nitrogen sources in fertilizers in recent years has made late applications less essential for fertilizer efficiency than formerly, except on sandy soils.

Side dressings of fertilizer should be made when the crop is grown on coarse sandy loams and coarse-textured subsoils subject to excessive leaching and on soils inadequately fertilized at the time of planting.

Nitrogen fertilizers suitable for side dressing cotton include materials manufactured by war-ammunition plants and allotted to agriculture. In addition to sodium nitrate and ammonium sulfate—commonly used materials — ammonium nitrate may give good results. Ammonium liquors containing nitrate and ammonia or ammonia and urea are available, but limited commercial use has been made of them, owing to the difficulty of storing and applying them. With the increased production of this class of nitrogen fertilizer they will be used more generally for side dressings. In determining the material most profitable to use in adding nitrogen to the soil, it is well to know (1) the cost per pound of nitrogen; (2) the acidity or basicity of the fertilizer; (3) the quantity of plant food it contains; (4) its physical properties, such as absorption of moisture and its tendency to cake; (5) its ease of application; and (6) its leaching-resistant qualities.

On potash-deficient soils where it is not practicable to supply adequate fertilizer at planting to correct the deficiency, cotton may be benefited by a side dressing of potash as well as of nitrogen.

Approximately half the nitrogen used on cotton is applied after

the cotton is up, as shown in table 2. An estimated average rate of 13 pounds of nitrogen per acre, based on the entire acreage of the State, is used in South Carolina, 11.6 pounds in North Carolina, 8 in Alabama, and 8.9 in Georgia. The most profitable quantity to use in delayed applications may vary with soil conditions and previous fertilizer applications. A total of about 36 pounds of nitrogen per acre is profitable on most soils. The estimated acreage of cotton that was side-dressed and the rates of nitrogen used in 1943 are also shown in table 2.

SIDE PLACEMENT OF FERTILIZERS

Placement of fertilizers to the side of the seed contributes to its efficient use. Low germination, delayed plant emergence, retarded seedling growth, and poor stands may result when the fertilizers are placed too near to or in contact with the seed. Field experiments comparing different methods of fertilizer placement, conducted for about 12 years in the principal cotton-producing States on representative soil types, demonstrated that better stands of cotton and greater returns from fertilizer will result when application is made simultaneously with seed planting and placement is made in narrow bands approximately 2½ inches to one or both sides of the seed row and 1½ to 2 inches below the seed level. The average yield of seed cotton from fertilizers applied to the side of the seed at the time of planting was 250 pounds per acre greater than when the same quantity was applied in the furrow and the seed planted above this.

The placement of the fertilizer in relation to the placement of the seed has a marked effect on rapidity of germination of cotton, on plant emergence, and on the total number of seeds germinating, as well as on cotton yield (fig. 7). The number of cottonseed emerging

FIGURE 7.—Effect of the placement of 600 pounds per acre of 4-8-8 fertilizer on cotton-plant stand. Rows 1 and 4 show results of applying fertilizer 2 inches to the side and 1½ inches below the seed level in one operation, with a fertilizer distributor-and-planter combination. Rows 2, 3, and 5 show results of applying fertilizer in a furrow, bedding it on, and planting cotton above the fertilizer band in two operations—fertilizer application and seed planting.

early, as shown in experiments in the Southeastern States, was approximately 50 percent greater with side placement of fertilizers than with underseed placement. The average result in several States over a 9-year period show that 95 percent of the seed germinated

when the fertilizer was placed in bands to the side and 62 percent when fertilizer was placed in a band under the seed. This indicates that 33 percent more seed will germinate when the fertilizer is applied to the side than when it is placed under the seed.

One- and two-row cotton planters with suitable side-placement fertilizer depositors are available commercially in both horse- and tractor-operated types, somewhat similar to a combined distributor and planter developed by the United States Department of Agriculture (fig. 8). One- and two-row fertilizer distributors and cotton-planter attachments for tractors also are available (fig. 9). Walking-type distributors with depositor for applying fertilizers in two

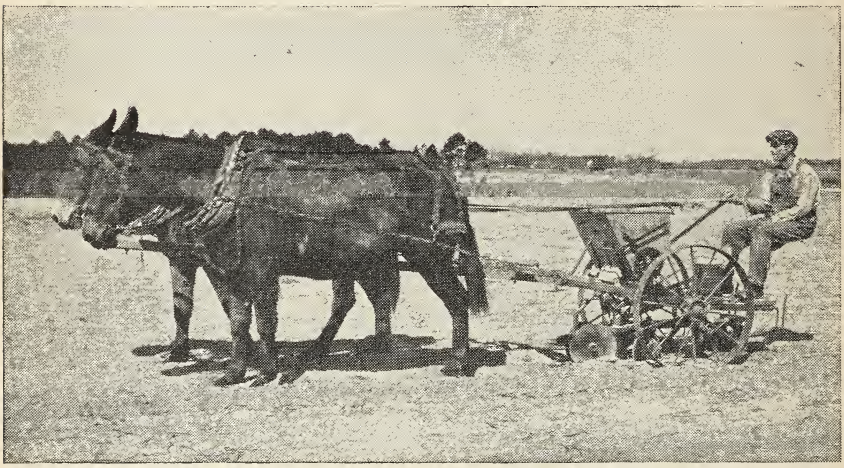


FIGURE 8.—Single-row mule-drawn cotton planter, with fertilizer attachment for side placement of fertilizers, in general use in many sections of the Cotton Belt.

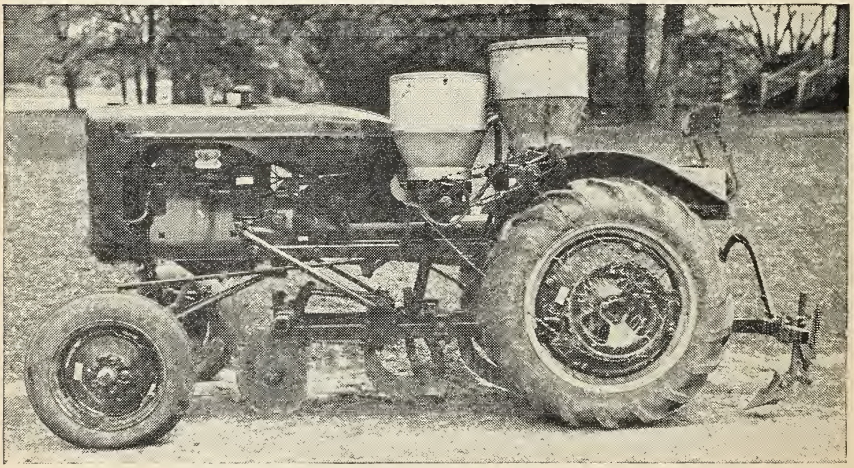


FIGURE 9.—Fertilizer-distributor attachment for tractor equipment, which beds the row, plants cottonseed, and applies fertilizer to side of the seed in one operation.

parallel bands and planting as a separate operation are on the market. A one-mule side-placement fertilizer distributor-and-planter combination (fig. 10), developed by the North Carolina Agricultural Experiment Station and available commercially, has been used with good results by small growers.

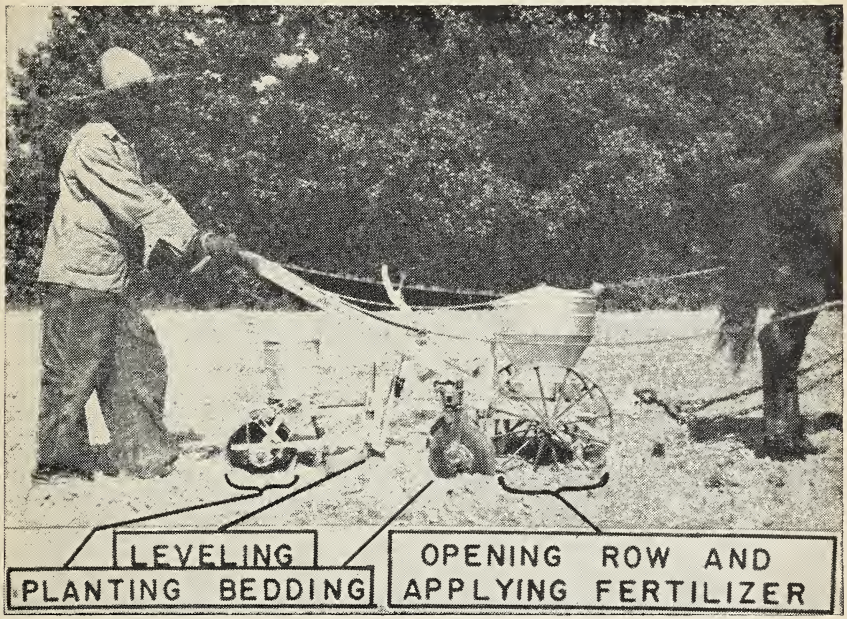


FIGURE 10.—One-mule once-over fertilizer distributor and planter fertilizes, beds, and plants in one operation. (Courtesy of North Carolina Agricultural Experiment Station.)

SAVINGS EFFECTED BY USE OF HIGHER ANALYSIS FERTILIZERS

As the relative efficiency of different forms of nitrogen does not vary widely when properly compounded, the cost factor is important in selecting nitrogen for direct application or for use in mixed fertilizers for cotton. New and more concentrated nitrogen materials available for fertilizers have been developed and used in large quantities in recent years. Private and wartime Government plants have been manufacturing and releasing for agricultural use large quantities of this class of fertilizers.

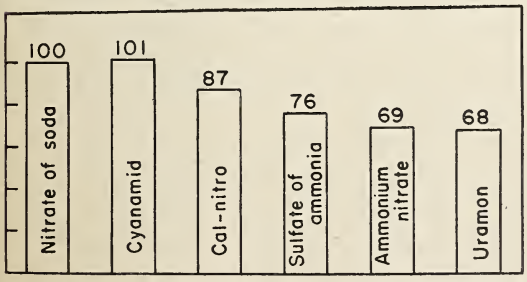
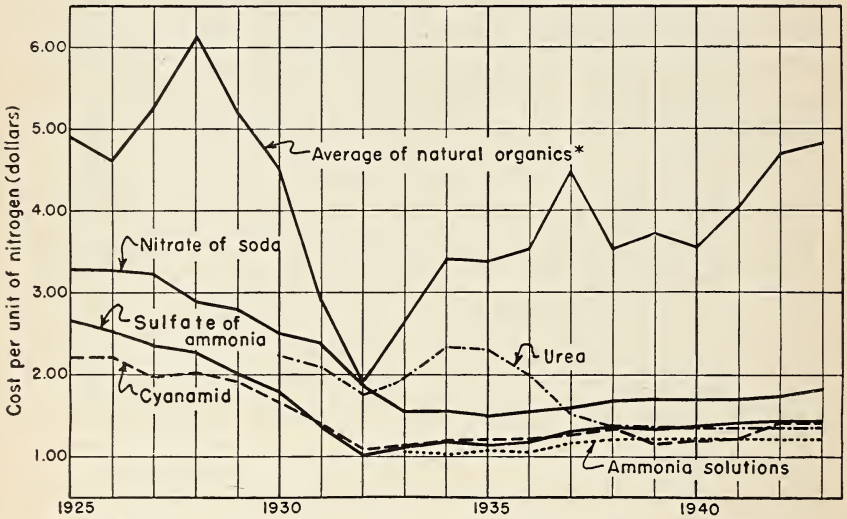


FIGURE 11.—Relative retail cost per unit of nitrogen of six nitrogen-fertilizer materials at Charleston, S. C., in 1944.

The relative retail cost per unit of nitro-

gen of six nitrogen-fertilizer materials in 1944 at Charleston, an important southern manufacturing point, is shown in figure 11. All these are used extensively for cotton with good results. Their nitrogen content is about as follows: Sodium nitrate, 16 percent; cyanamid, 22; Cal-Nitro, 15; sulfate of ammonia, 20; ammonium nitrate, 32; and Uramon, 42. Great differences are found in the cost of these materials. Sodium nitrate and cyanamid are the most expensive, and ammonium nitrate and Uramon, two of the highly concentrated materials, are cheaper per unit of nitrogen. Progress has been made in reducing the cost of nitrogen in recent years, as shown in figure 12, which gives the wholesale price in bulk at port or producing point.



* 1925-32 Average of prices for fish scrap, dried blood, cottonseed meal, and tankage.

1933-43 Average of prices for castor pomace, cottonseed meal, animal tankage, process tankage, and fish scrap.

FIGURE 12.—Wholesale price in bulk at ports and producing points of nitrogen-fertilizer materials.

The cost of nitrogen fertilizers, except natural organic nitrogen, has declined since 1925. The demand for natural organic nitrogen for stock feed has increased the cost of these materials and greatly reduced the tonnage used in fertilizer. The use of the less expensive forms, which is possible without reducing fertilizer efficiency, results in a substantial saving to cotton growers.

Somewhat less can be saved by the use of the more concentrated superphosphate. The relative cost of the different grades varies in different sections of the country. For instance, in Atlanta 20-percent superphosphate was 4 percent cheaper per unit of phosphoric acid than 18-percent superphosphate, while in Shreveport 20-percent superphosphate was 7 percent cheaper per unit of phosphoric acid than the 18-percent material. Figure 13 shows the relative cost per unit of phosphoric acid in 1944 at these two markets.

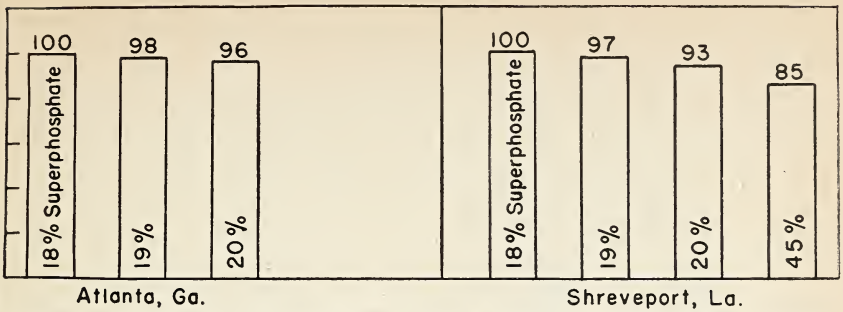


FIGURE 13.—Relative retail cost per unit of phosphoric acid in three grades of superphosphate at Atlanta, Ga., and four grades at Shreveport, La., in 1944.

The relatively lower cost of high-grade as compared with low-grade phosphate at Shreveport is due to higher transportation and handling charges to that point because of its greater distance from the source of supply. Ten bags, that is, 2,000 pounds, of 18-percent superphosphate supply 360 pounds of phosphoric acid, while 9 bags, or 1,800 pounds, of 20-percent superphosphate and 800 pounds (four bags) of 45-percent superphosphate supply an equal quantity of phosphoric acid. The low-grade superphosphate not only costs more but involves more labor on the farm for drayage, storage, and application per unit of phosphoric acid.

Muriate of potash, formerly imported from Europe, was 50-percent grade; now American companies produce 60-percent or higher analysis potash in the refining processes. No low-grade potash has been imported since 1938 and no kainit of the early type. Kainit marketed in recent years is a mixture of muriate of potash and common salt of approximately 20-percent potash content. One ton of 60-percent muriate of potash supplies as much potash as 3 tons of 20-percent kainit. The 2 extra tons are common salt or inert filler that are of little value to crops. The relative cost per unit of potash in different grades in Atlanta in 1944 is shown in figure 14. The cost per unit of potash in muriate of potash increases as the concentration of potash decreases. The wholesale cost per unit of potash for three potash sources since 1910 is shown in figure 15. In general, the cost of potash declined from 1910 to 1938 since 1939 it has been fairly stationary. Sulfate of potash,

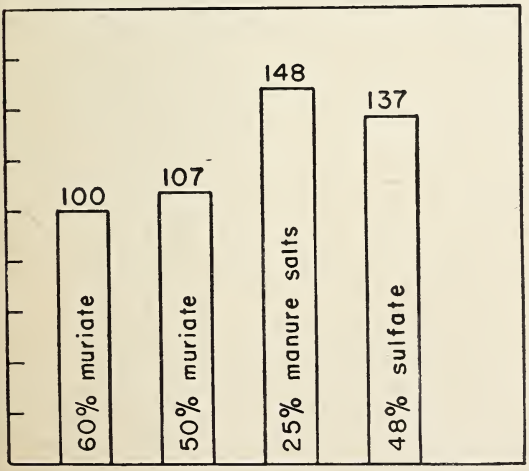


FIGURE 14.—Relative retail cost per unit of potash in four grades of potash at Atlanta, Ga., in 1944.

owing to manufacturing processes, has always been the most expensive source of potash. It is apparent that the grade of potash used on cotton is a factor in the fertilizer cost.

In recent years the manufacture of nitrogen salts of high concentration and phosphate of high phosphoric value, together with the availability of high-grade potash salts, has made it possible to manufacture mixed fertilizers of higher plant-food content at a reduced cost per unit of plant food. The cost of commercial mixed fertilizers is determined by (1) the cost of the materials to the fertilizer manufacturer and (2) the cost of manufacture, bags, and distribution. The cost of manufacturing and distributing mixed fertilizers in the Southeastern States, exclusive of materials, is estimated, on a prewar basis, to range from $11 to $12 per ton. This cost is approximately the same, regardless of the nutrient content of the mixed fertilizers. Thus, when a farmer buys fertilizers containing 24 percent of plant food, for example, he pays for freight, bags, and other costs on only two-thirds as much material as when he buys a fertilizer containing only 16 percent of plant food.

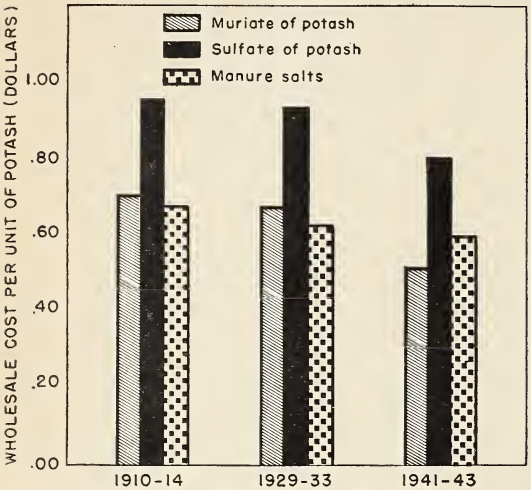


FIGURE 15.—Wholesale cost per unit of potash for three potash materials, 1910-43.

The relative cost per unit of plant food in four grades of fertilizers to farmers in the Southeastern States in 1943, based on ceiling prices designated by the Office of Price Administration, is given in figure 16. The cost per unit of plant food was 5, 10, and 15 percent less, respectively, in 5-10-5, 6-12-6, 8-16-8 grades than in a 4-8-4. Fertilizer containing 24 units or more of plant food, as a 6-12-6, may be prepared by selecting fertilizer materials so that limestone or other filler is not necessary to make the desired analysis. This fertilizer is acid-forming. The use of high-grade acid-forming fertilizer is more economical than a lower grade, 4-8-4, with limestone filler, but the land should receive broadcast applications of limestone at 4- to 5-year intervals.

The limestone used in the fertilizer-manufacturing process is more costly to farmers than the same material purchased in bulk. Limestone or other filler used in mixed fertilizers has an estimated cost of approximately $12 per ton as compared with $5 in large quantities to farmers. Lime can be used more economically in broadcast applications, with beneficial results both to the cash crop and to the legumes grown in rotation for soil improvement. A 16-unit fertilizer containing approximately 400 pounds of limestone per

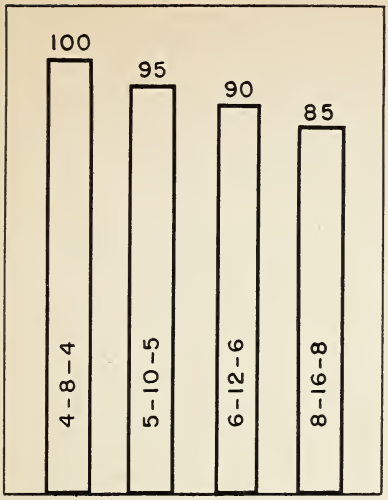


FIGURE 16.—Relative cost per unit of plant food in four grades of fertilizers to farmers in the Southeastern States in 1943.

ton as filler to make it non-acid-forming costs the farmer approximately $2.40 for the limestone. The 400 pounds of limestone purchased in bulk cost him $1. A farmer using 333 pounds per acre of a 24-unit fertilizer annually and 1 ton of limestone in 5 years spends $6.90, as compared with $7.35 for the same nutrients in a 16-unit non-acid-forming fertilizer.

Substantial savings in cotton production costs are made by using the higher analysis fertilizers. For cotton growers, high-analysis fertilizers supply more plant food for less money. At the same time they are more efficient fertilizers, require less labor in handling, and effect a saving in application. For manufacturers there is a saving in bags, labor, and wear on machinery, and for the Nation a saving in freight-car space for other uses, essential both during the war and in the postwar period.

RECOMMENDATIONS TO INCREASE YIELDS

The acre yields of cotton may be increased and the cost of production reduced by (1) increased use of improved fertilizers, (2) growing winter legume crops on more acreage, (3) rotating cotton with other crops, including a summer legume, and (4) improved cultural practices.

A farmer who plants 50 acres of cotton can expect an increased production of 2,000 pounds of lint cotton by adding 100 pounds more fertilizer per acre, assuming that the 100 pounds produces 40 pounds of lint. He would obtain an additional 4,250 pounds of lint by applying the fertilizer to the side of the seed and planting the cotton in one operation with a combination planter-and-fertilizer distributor. This method of applying fertilizer gives an estimated increase of 85 pounds per acre of lint over the commonly used method of placement under the seed. Assuming that the farmer's normal yield is 375 pounds of lint per acre, the acreage planted could be reduced from 50 to about 34 without a decrease in production.

Fertilizing cotton and increasing the available plant nutrients of the soil by growing and turning under winter legume cover crops should give an average increased yield of approximately one-fifth of a bale an acre over winter fallow land on a large acreage. Statistics giving acreage of land used for cotton production that is planted to winter legumes are not available. In 1942, however, 1,981,465 acres of winter legumes were planted as a soil-building practice on all cropland in 12 Southeastern and South Central States (5). The acreage planted to cotton in these States the following year (1943)

was 20,942,000. The figures indicate the small percentage of cotton acreage that benefit by winter legumes and points out the opportunity for increasing cotton production by winter cover crops.

Increased cotton yields of approximately one-seventh of a bale per acre may be obtained by rotating with other crops, including a summer legume, since this practice maintains the organic-matter content of the soil, supplies nitrogen, and makes other nutrients in the soil available to cotton.

An average increase in acre yields of approximately 33 pounds of lint cotton per acre, indicated by experimental data (*7, 18*), results from such improved cultural practices as terracing, use of tractor equipment, deep seedbed preparation, early breaking of land, and frequent cultivation.

An increase of 100 pounds an acre of improved fertilizer above the quantity used in general practice on approximately 10,000,000 acres in the fertilizer-using Cotton Belt should yield an estimated increase of 800,000 bales. The adoption of improved methods of applying fertilizer in the large fertilizer-using belt of the Southeastern States, which comprised 5,190,000 acres in 1943, should result in an estimated increased yield of 865,000 bales. By increasing fertilizer use accordingly, by adopting side placement of fertilizers, and by using combined planter-and-fertilizer distributors, normal production can be maintained on fewer acres. It is estimated that between 2,500,000 to 3,000,000 acres could be released from cotton cultivation by increasing the fertilizer by 100 pounds per acre and by side placement without a probable decrease in production.

The efficient use of high-analysis improved fertilizers manufactured at a lower cost per unit of plant food and the utilization of less farm labor for handling, storing, and applying should result in a larger acre yield at a lower production cost. An increase in the nitrogen, phosphoric acid, and potash content of fertilizers from 16 units, as a 4-8-4, formerly used extensively for cotton, to 20 units (5-10-5), recommended generally for cotton and authorized for manufacture in the Southern States by the War Food Administration, lowers the cost per unit of plant food approximately 5 percent. A further increase from 20 to 24 units, as in a 6-12-6, or to 32 units, as in a 8-16-8, would further lower the cost 10 and 15 percent, respectively.

Data assembled by the Southern Regional Office of the Soil Conservation Service and presented graphically in figure 17 show the effects of crop management and cultural practices, including the elimination of unsuitable land, on cotton production on 1,829 widely scattered farms in the Southeastern States. The yield of lint cotton increased from 294.5 to 385.1 pounds per acre, or 30.8 percent, resulting in the production of 30,026 bales on 40,155 acres, as compared with 29,207 bales on 49,590 acres. The survey, completed in 1942 after soil-improvement practices had been followed for 2 to 3 years, indicates that 19 percent less acreage planted to cotton in the Southeastern States need not reduce actual cotton production if improved cultural, crop, and soil-management practices are adopted generally.

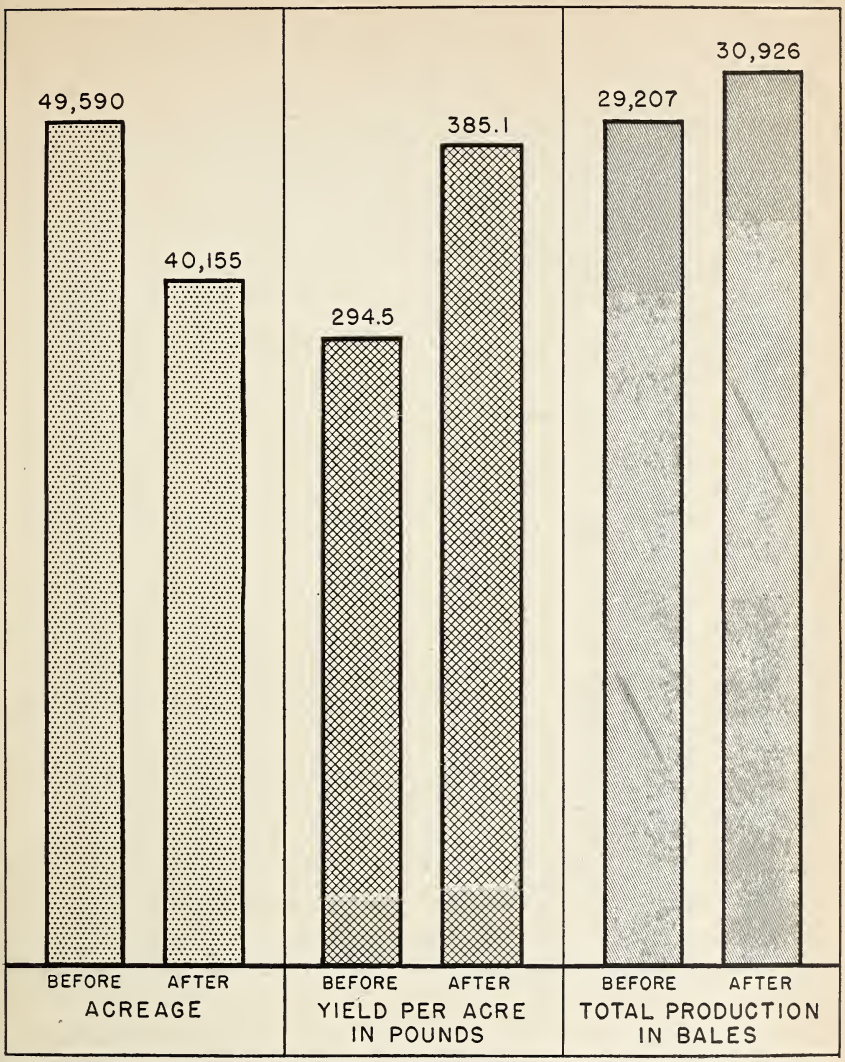


FIGURE 17.—Cotton acreage, yields, and production on 1,829 farms in the Southeastern States before and after the practice of growing winter legume cover crops, the adoption of crop rotations, including a summer legume, and the elimination from cotton culture of unsuitable land. (Courtesy of the Soil Conservation Service, Southern Regional Office, Spartanburg, S. C.)

LITERATURE CITED

(1) AGELASTO, A. M., DOYLE, C. B., MELOY, G. S., and STINE, O. C.
1922. THE COTTON SITUATION. U. S. Dept. Agr. Yearbook 1921: 323–406, illus.

(2) ALLISON, F. E.
1929. CYANAMID, ITS USES AS A FERTILIZER MATERIAL. U. S. Dept. Agr. Cir. 64, 12 pp., illus.

(3) BUREAU OF CHEMISTRY AND SOILS, SOIL SURVEY DIVISION.
1938. SOILS OF THE UNITED STATES. U. S. Dept. Agr. Yearbook 1938: 1019–1161, illus.

(4) Cooper, H. P.
1941. PLANT-NUTRIENT DEFICIENCY SYMPTOMS IN COTTON. Pp. 125–148, illus. *In* Hambidge, G., ed., Hunger Signs in Crops. 327 pp., illus. Washington.

(5) Dodd, N. E.
1943. REPORT OF THE CHIEF OF THE AGRICULTURAL ADJUSTMENT AGENCY, 1943. U. S. Dept. Agr. War Food Admin. Ann. Rpt. 1943, 45 pp.

(6) Fletcher, C. C., Merz, A. R., and Brown, B. E.
1940. PRODUCTION AND AGRICULTURAL USE OF AMMONIUM SULFATE. U. S. Dept. Agr. Cir. 578, 15 pp.

(7) Jones, T. N., Hamblin, I. E., and Leonard, O. A.
1941. WEED CONTROL AND COTTON TILLAGE ON BLACKBELT (PRAIRIE) SOILS. Miss. Agr. Expt. Sta. Tech. Bul. 29, 64 pp., illus.

(8) Leighty, C. E.
1938. CROP ROTATION. U. S. Dept. Agr. Yearbook 1938: 406–430, illus.

(9) McKee, R.
1935. SUMMER CROPS FOR GREEN MANURE AND SOIL IMPROVEMENT. U. S. Dept. Agr. Farmers' Bul. 1750, 16 pp., illus.

(10) ——— and McNair, A. D.
1931. WINTER LEGUMES FOR GREEN MANURE IN THE COTTON BELT. U. S. Dept. Agr. Farmers' Bul. 1663, 20 pp., illus.

(11) McNair, A. D., and McKee, R.
1933. THE USE OF WINTER LEGUMES IN THE SOUTHEASTERN STATES. U. S. Dept. Agr. Tech. Bul. 367, 36 pp., illus.

(12) Merz, A. R.
1931. NEW FERTILIZER MATERIALS. U. S. Dept. Agr. Cir. 185, 14 pp., illus.

(13) ———
1938. SELECTING FERTILIZERS. U. S. Dept. Agr. Cir. 487, 15 pp., illus.

(14) ——— and Brown, B. E.
1943. PRODUCTION AND FERTILIZER USE OF UREA. U. S. Dept. Agr. Cir. 679, 18 pp.

(15) ——— and Fletcher, C. C.
1937. PRODUCTION AND AGRICULTURAL USE OF SODIUM NITRATE. U. S. Dept. Agr. Cir. 436, 11 pp.

(16) Pieters, A. J., and McKee, R.
1938. THE USE OF COVER AND GREEN-MANURE CROPS. U. S. Dept. Agr. Yearbook 1938: 431–444, illus.

(17) Piper, C. V., and Pieters, A. J.
1922. GREEN MANURING. U. S. Dept. Agr. Farmers' Bul. 1250, 45 pp., illus.

(18) Randolph, J. W., Reed, I. F., and Gordon, E. D.
1940. COTTON-TILLAGE STUDIES ON RED BAY SANDY LOAM. U. S. Dept. Agr. Cir. 540, 54 pp., illus.

(19) Ross, W. H., and Mehring, A. L.
1938. MIXED FERTILIZERS. U. S. Dept. Agr. Yearbook 1938: 522–545, illus.

(20) Schreiner, O., Merz, A. R., and Brown, B. E.
1938. FERTILIZER MATERIALS. U. S. Dept. Agr. Yearbook 1938: 487–521, illus.

(21) Shorey, E. C.
1940. THE LIMING OF SOILS. U. S. Dept. Agr. Farmers' Bul. 1845, 25 pp., illus.

(22) Smalley, H. R., Engle, R. H., and Willett, H.
1939. AMERICAN FERTILIZER PRACTICES: SECOND SURVEY. 128 pp., illus. Washington.

(23) Troug, E.
1938. SOIL ACIDITY AND LIMING. U. S. Dept. Agr. Yearbook 1938: 563–580, illus.

☆ U. S. GOVERNMENT PRINTING OFFICE: 1945—637797

For sale by the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.